IR-Signature of the MULDICON Configuration Determined by the IR-Signature Model MIRA

Erwin Lindermeir*, Markus Rütten†
DLR – German Aerospace Center
***Remote Sensing Technology Institute**
†Institute of Aerodynamics and Flow Technology

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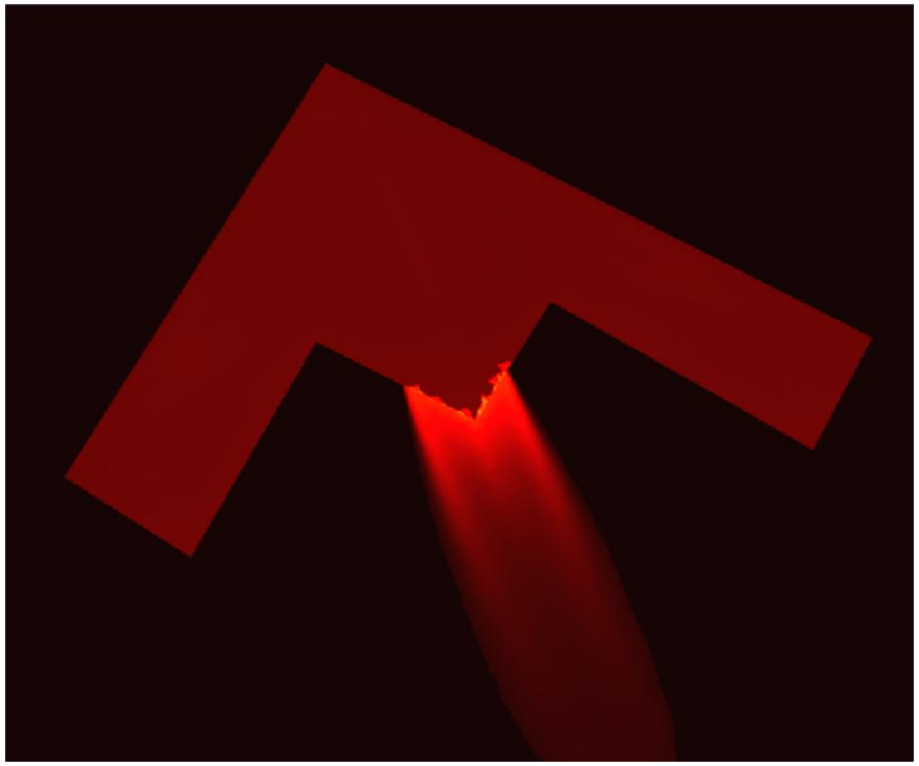
Outline

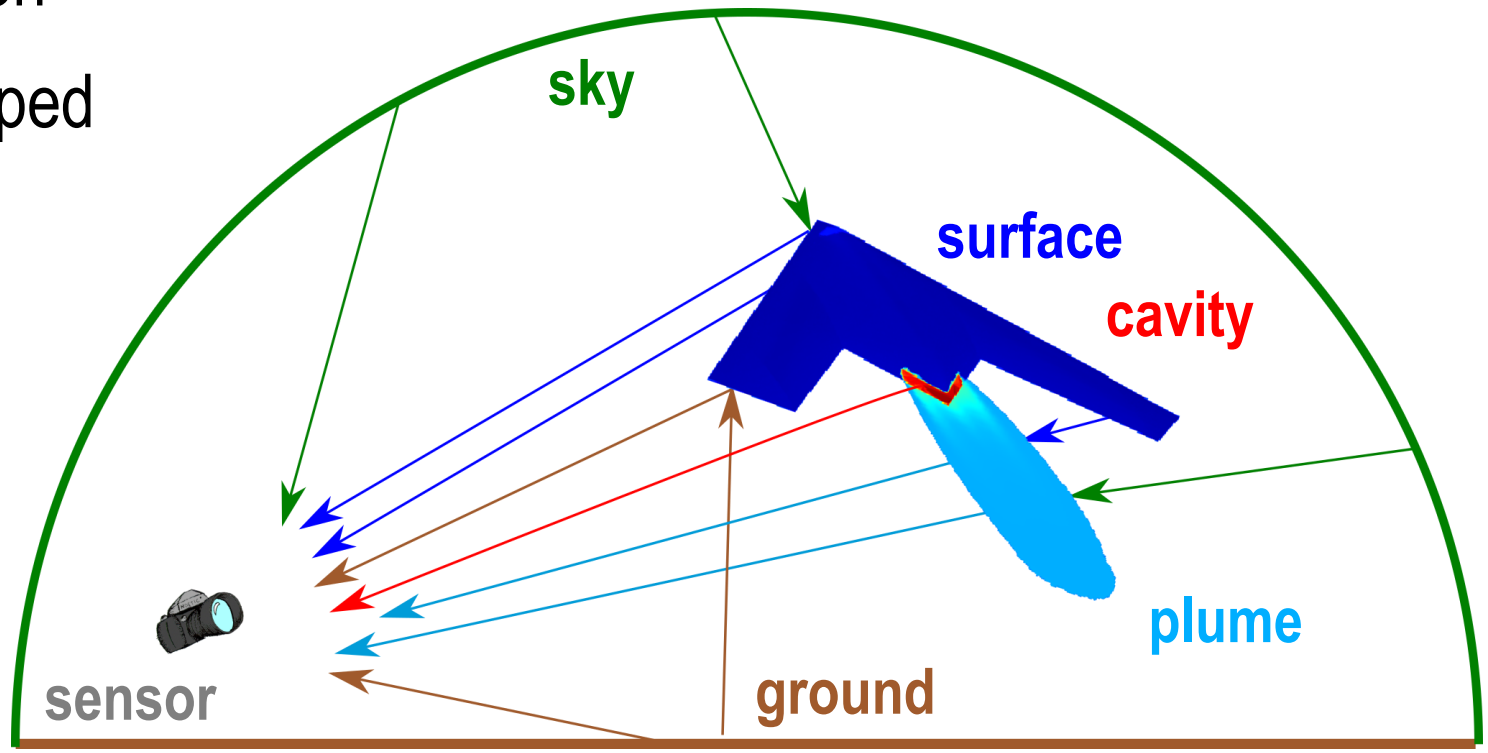
- The IR-Signature Model MIRA – Overview
- Application to IR-Signature Predictions for the MULDICON UCAV (NATO AVT-251)
- Summary



IR-Signature Model MIRA
Model for InfraRed Scene Analysis

Requirements

- Modeling of emission and reflection
- Radiative transfer in complex shaped exhaust duct and inlet
- Arbitrarily shaped exhaust gas
- Interference of exhaust gas and flow around aircraft



MIRA – Reflections

Method: Ray-tracing and Mote Carlo integration

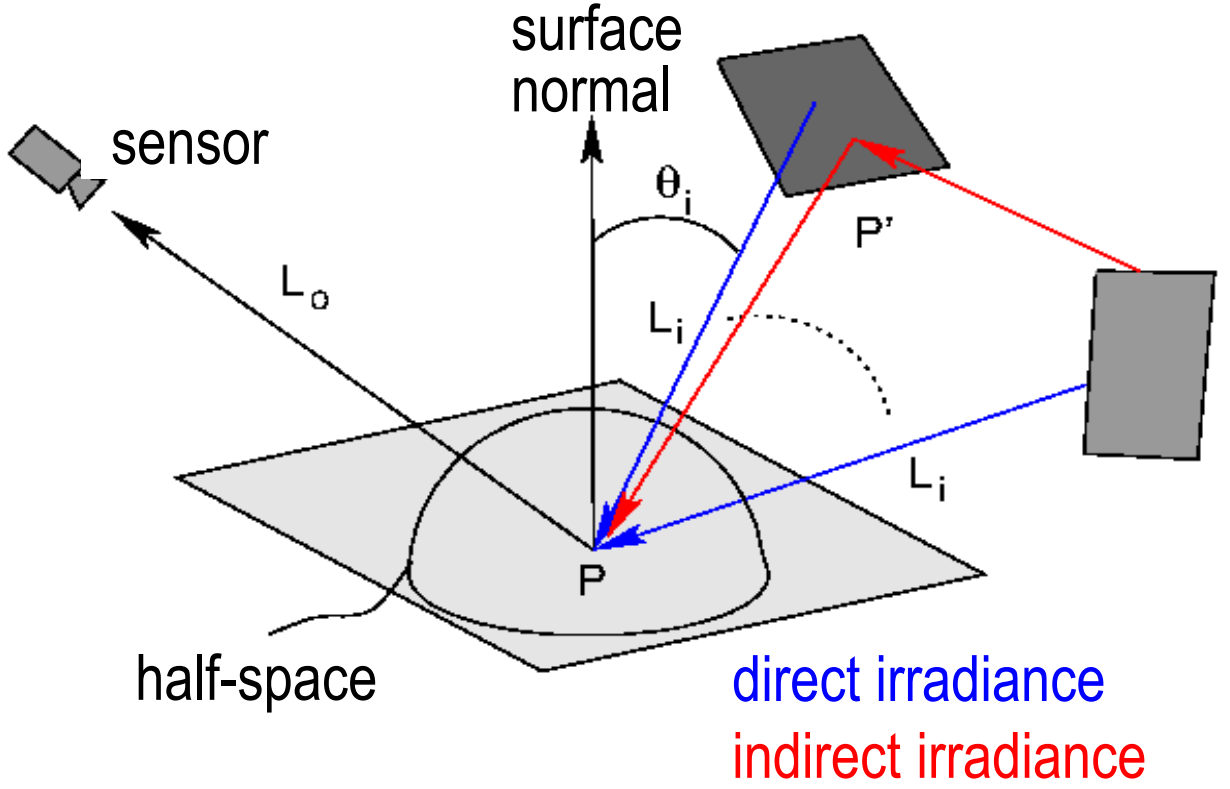
Direct irradiance (one reflection):

Simple method:

Directions of incidence from BRDF* **OR** radiance distribution on surfaces and integrate.

MIRA: Multiple importance sampling (MIS):

Directions of incidence from BRDF **AND** radiance distribution on surfaces and weight contributions



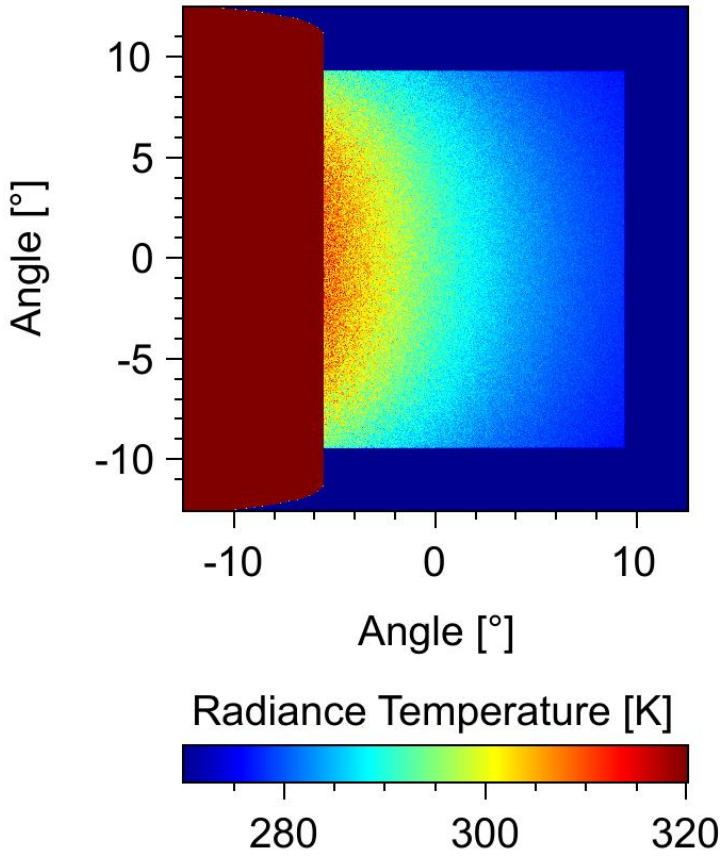
*BRDF = Bi-directional reflection distribution function

Efficiency of Multiple Importance Sampling

Cylinder (emissivity ε = 1, T = 400 K) in front of diffuse reflecting plate (ε = 0.6, T = 300 K)

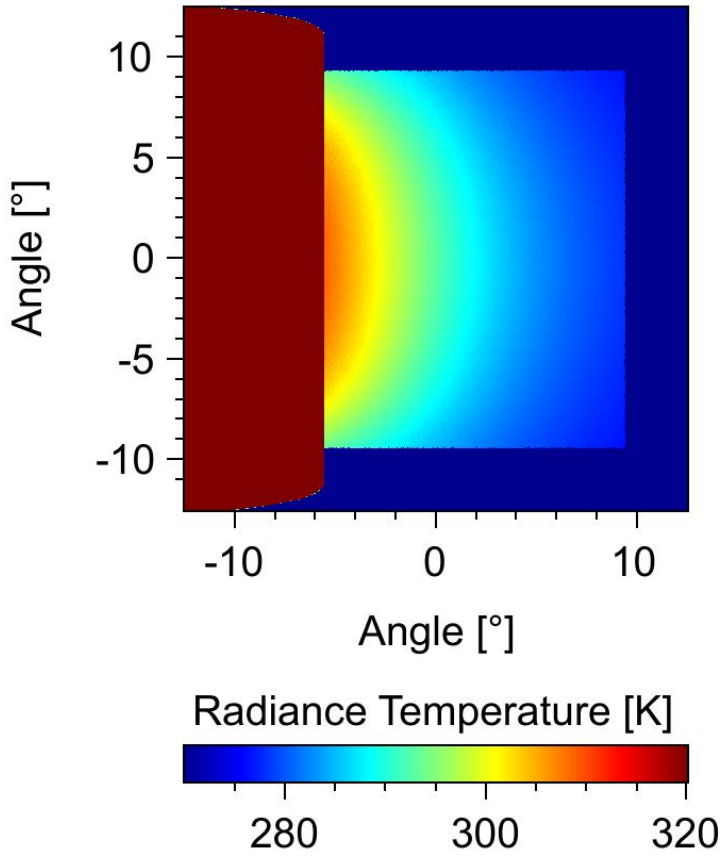
MIRA (simple)

256 rays per pixel, compute time: 22.5 s



MIRA (MIS)

4 rays per pixel, compute time: 5.6 s



Modeling Multiple Reflections

Path-Tracing

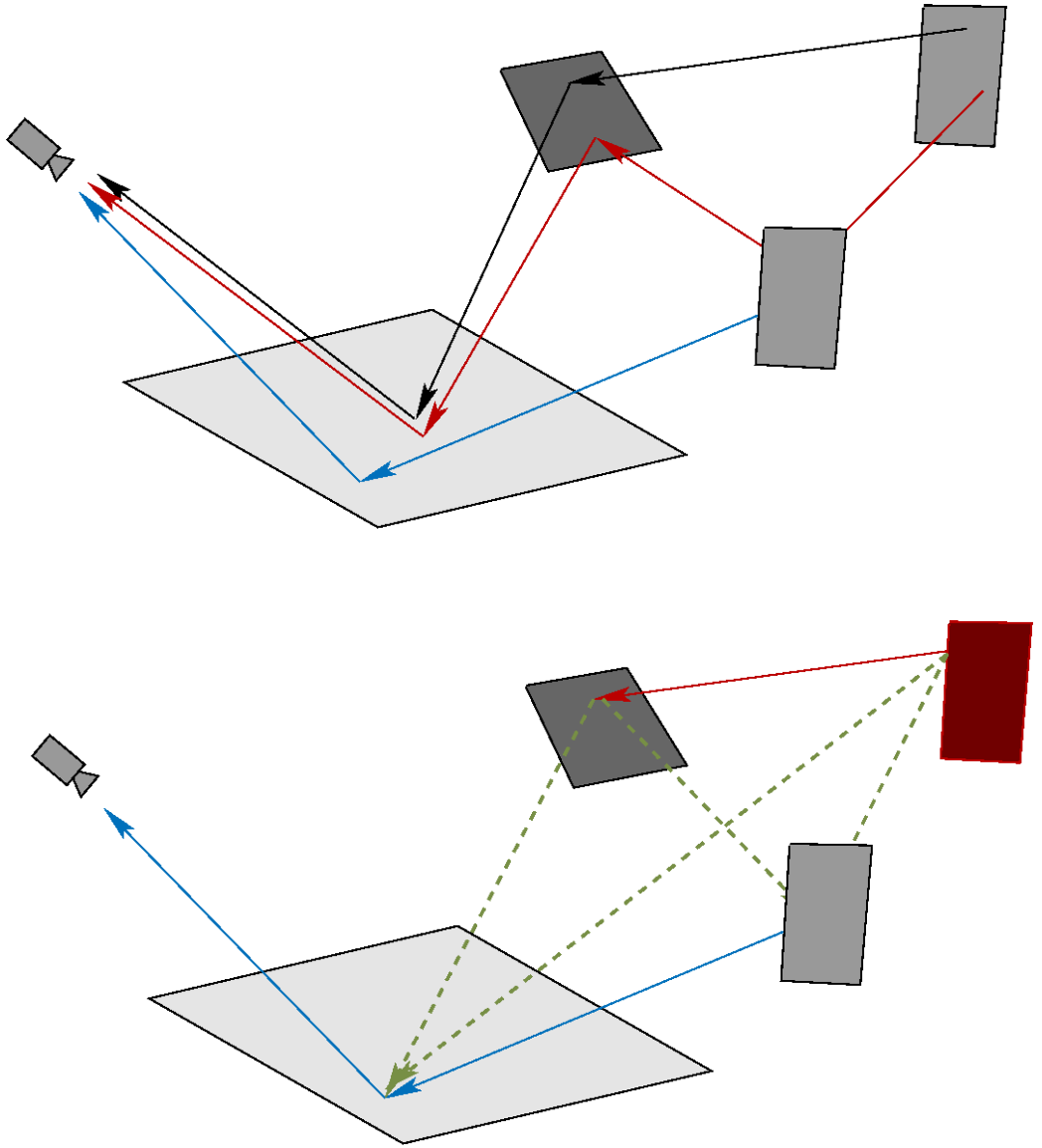
- Construction of „paths“ starting from the camera based on BRDF

Bi-directional Path-Tracing

- Construction of sub-paths starting from the camera and from (strong) radiators
- Connection of sub-paths of various lengths

Common

- Direct irradiance calculation at each intersection with geometry



IR-Signature Model MIRA

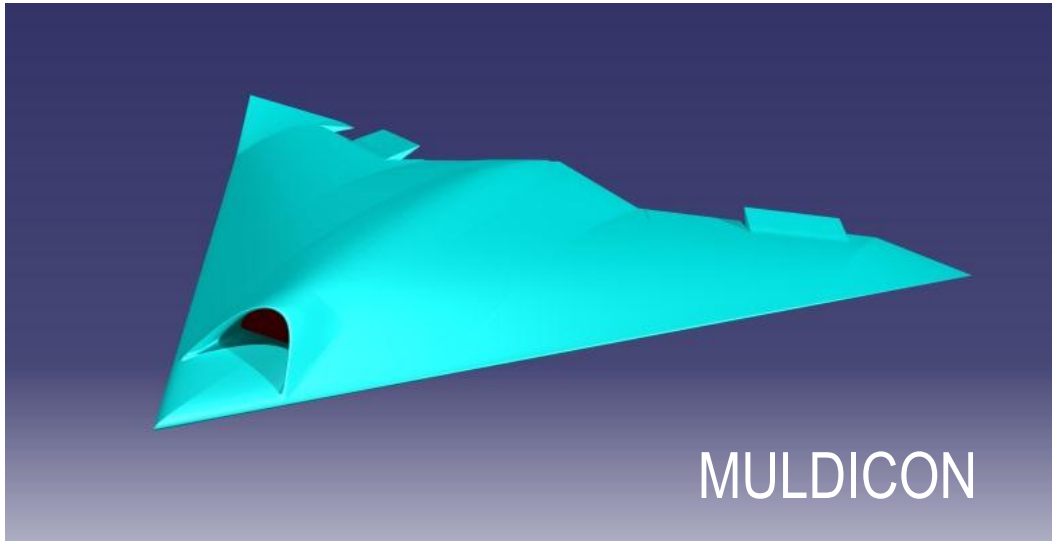
Further Capabilities

- Spectral Range: 2 – 20 µm
- Optimized sample generation: Low discrepancy sampler (and others)
- Interface to DLR TAU code to include CFD results (exhaust gas)
- Atmosphere and ground modeled by coupling to MODTRAN
- Terrain model to permit real landscape using a DEM (digital elevation model) and a surface classification.
- Output: Images, radiance spectra (a/c skin, exhaust duct, plume, background,…), contrast radiant intensity and irradiance

MIRA IR-Signature Predictions to Improve the exhaust duct of MULDICON

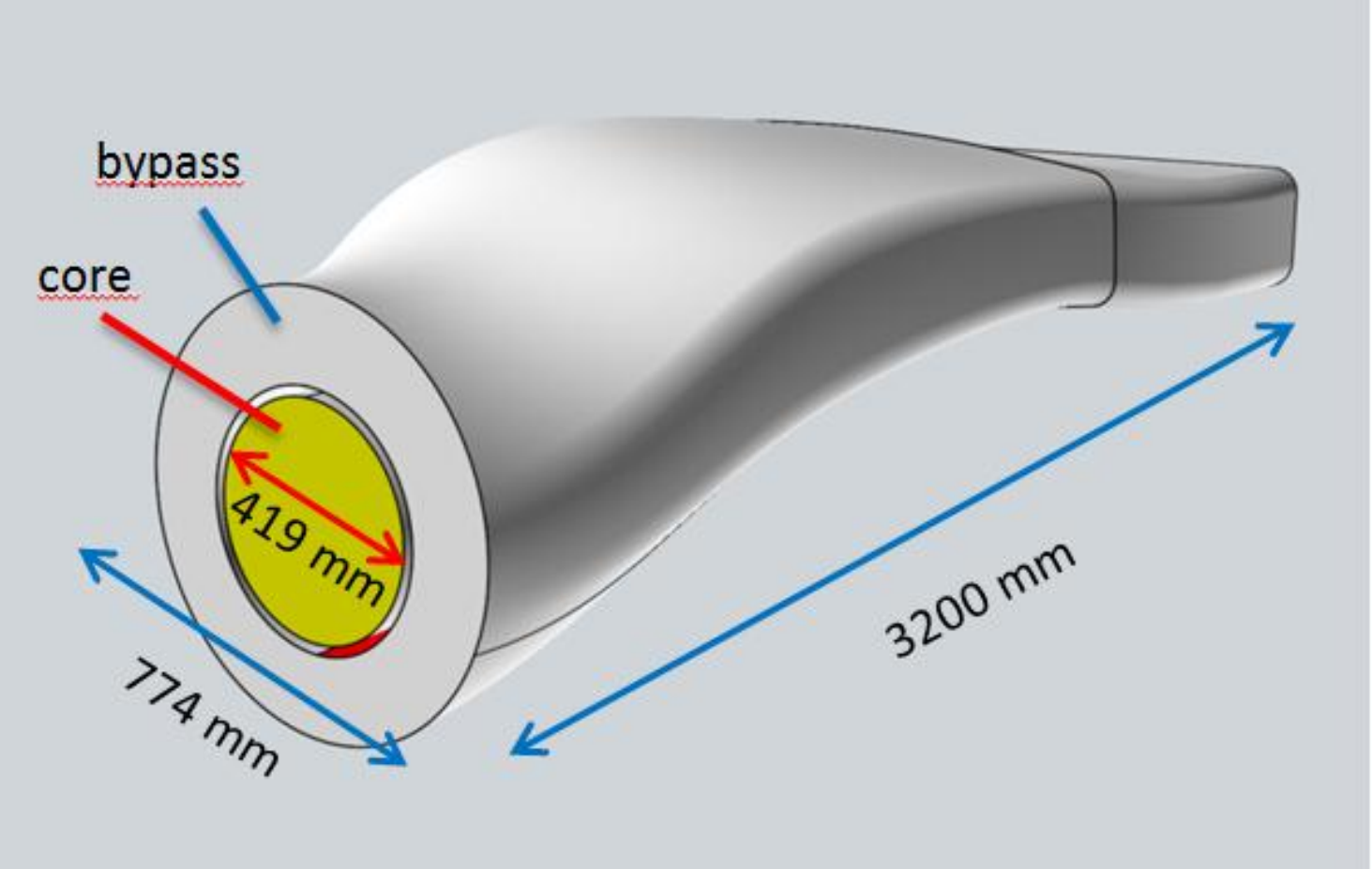
MULDICON

- Generic UCAV to demonstrate a multidisciplinary design approach
- Used in NATO AVT-251 and DLR project MEPHISTO



Courtesy of A. Schütte, DLR

Exhaust Duct Outer Shape



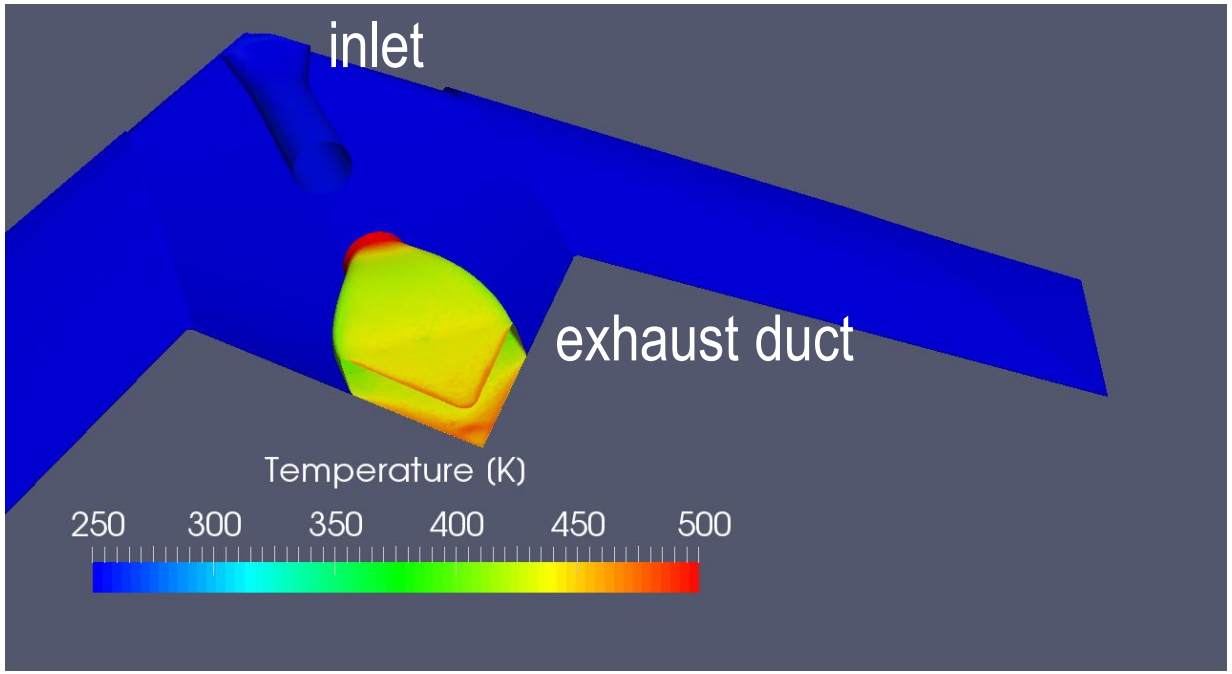
Temperature Distributions of Two Designs

DLR-F17

bypass ratio 2

max. thrust 35 kN

external mixing

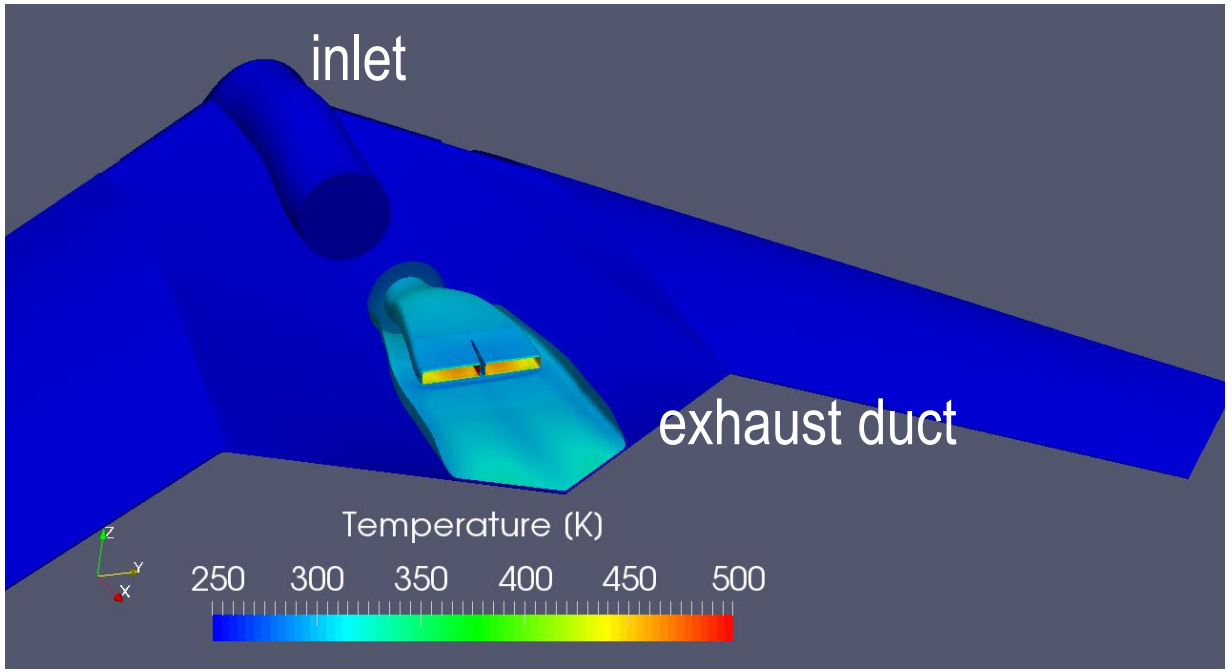


MULDICON

VCE*, max. bypass ratio 1.3

max. thrust 60 kN

internal mixing

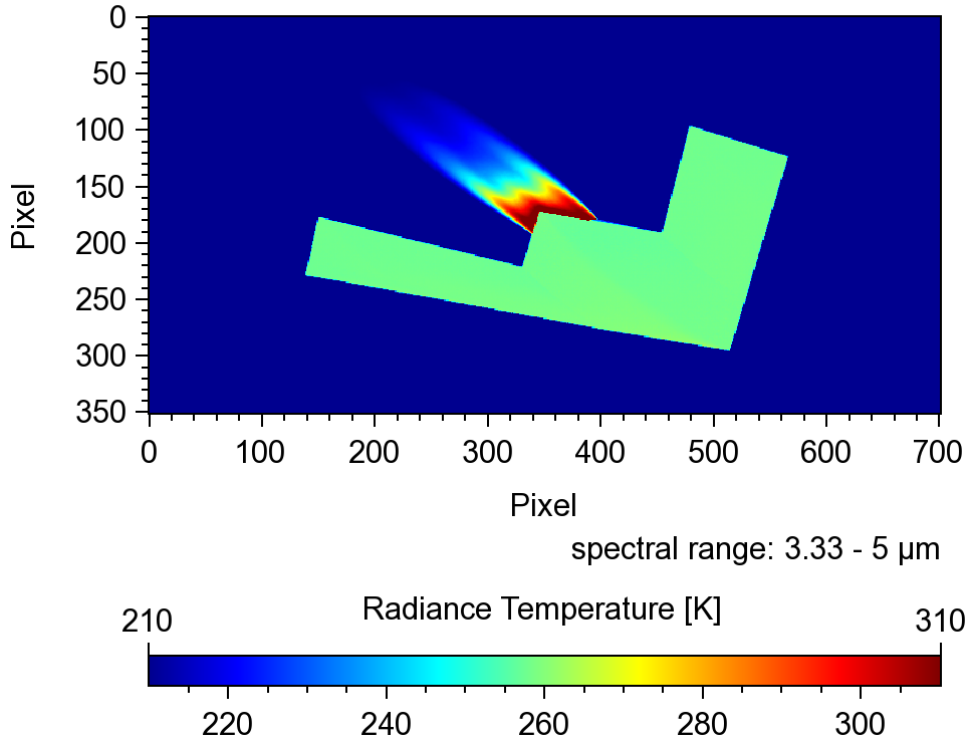


*VCE = variable cycle engine

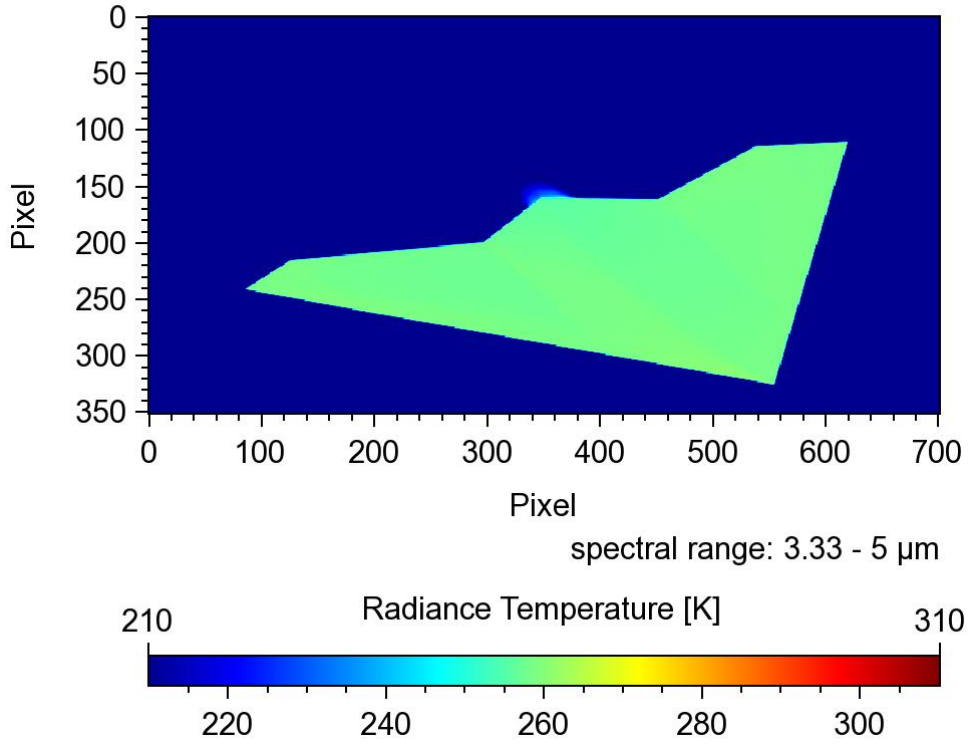
IR-Signature Comparison – View from below

View: Off-tail angle 30°, elevation –25°, distance 1 km, background clear sky
Velocity Mach 0.8, altitude 11 km

DLR-F17



MULDICON

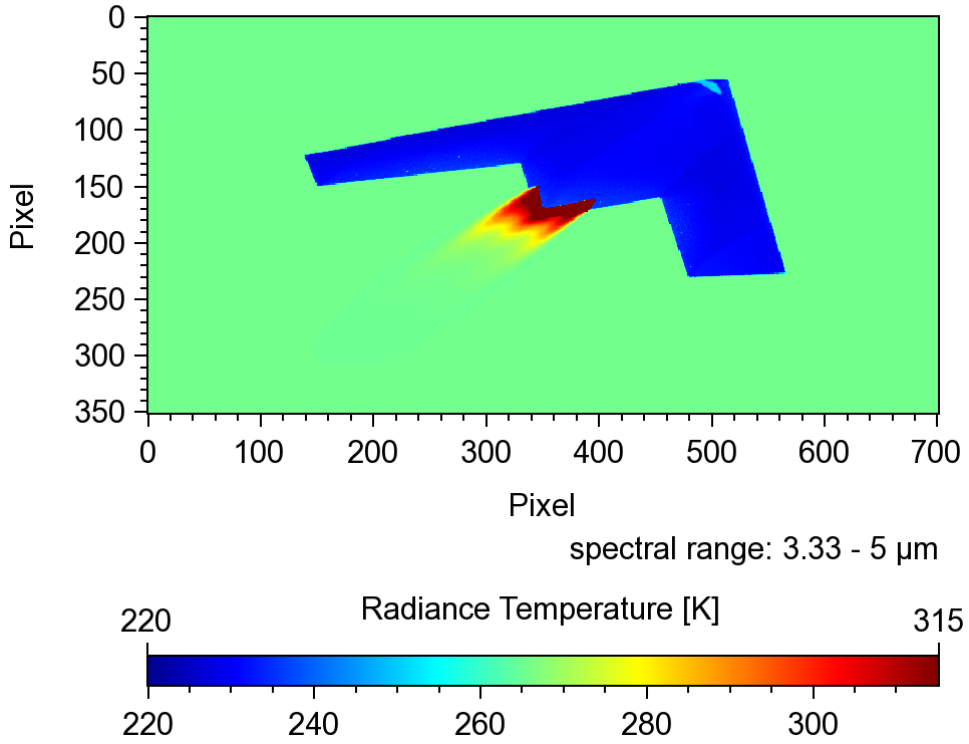


IR-Signature Comparison – View from above

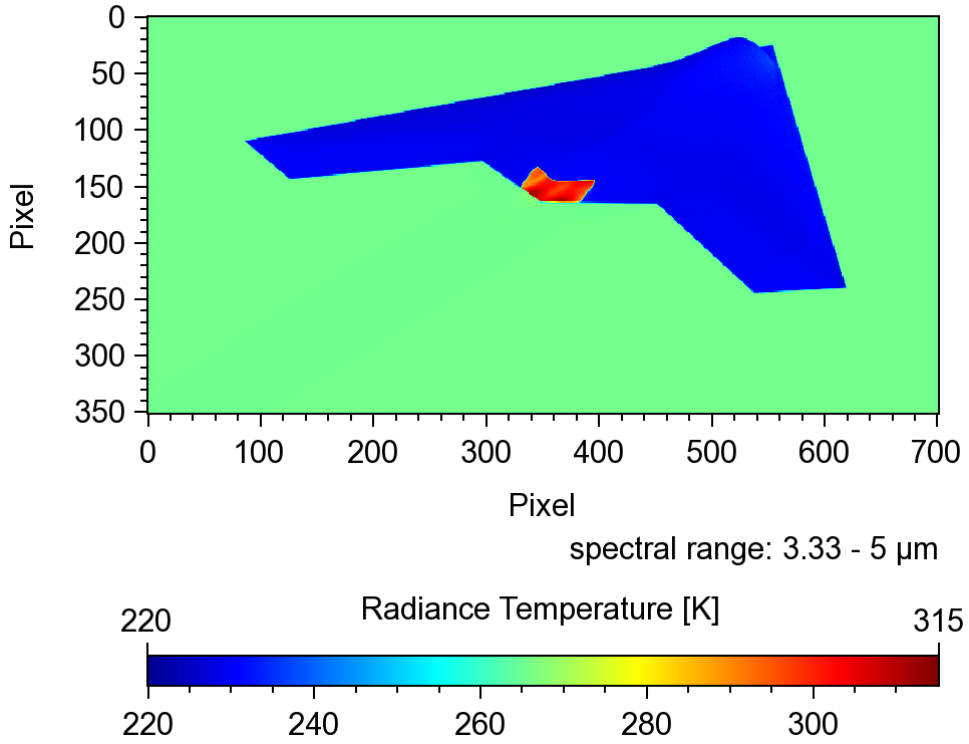
View: Off-tail angle 30°, elevation 25°, distance 1 km, homogeneous background

Velocity Mach 0.8, altitude 11 km

DLR-F17



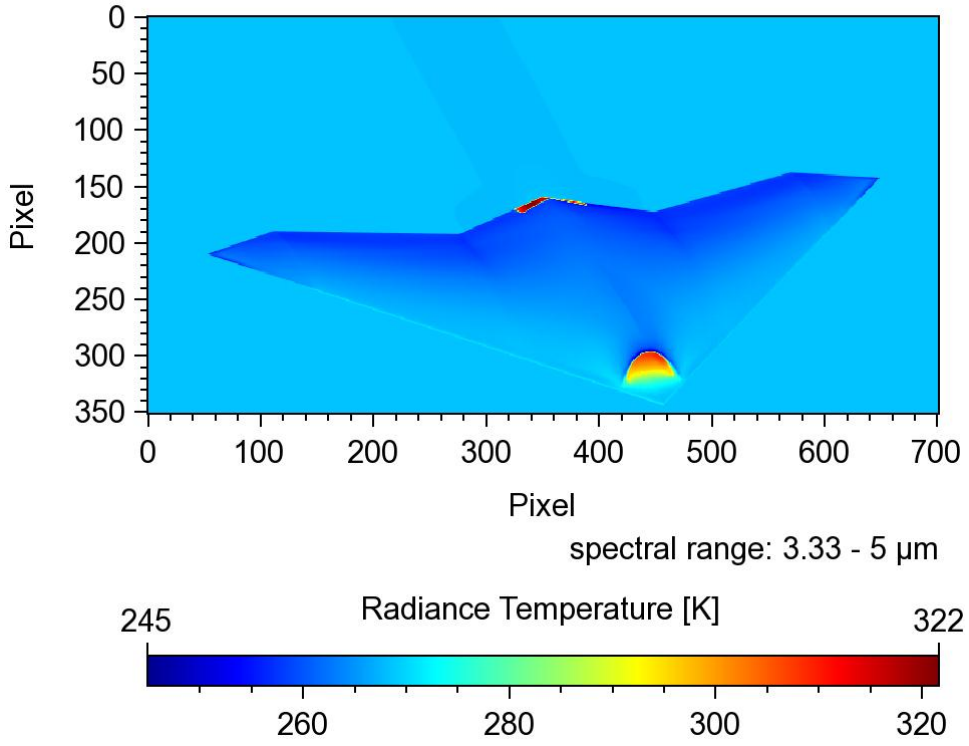
MULDICON



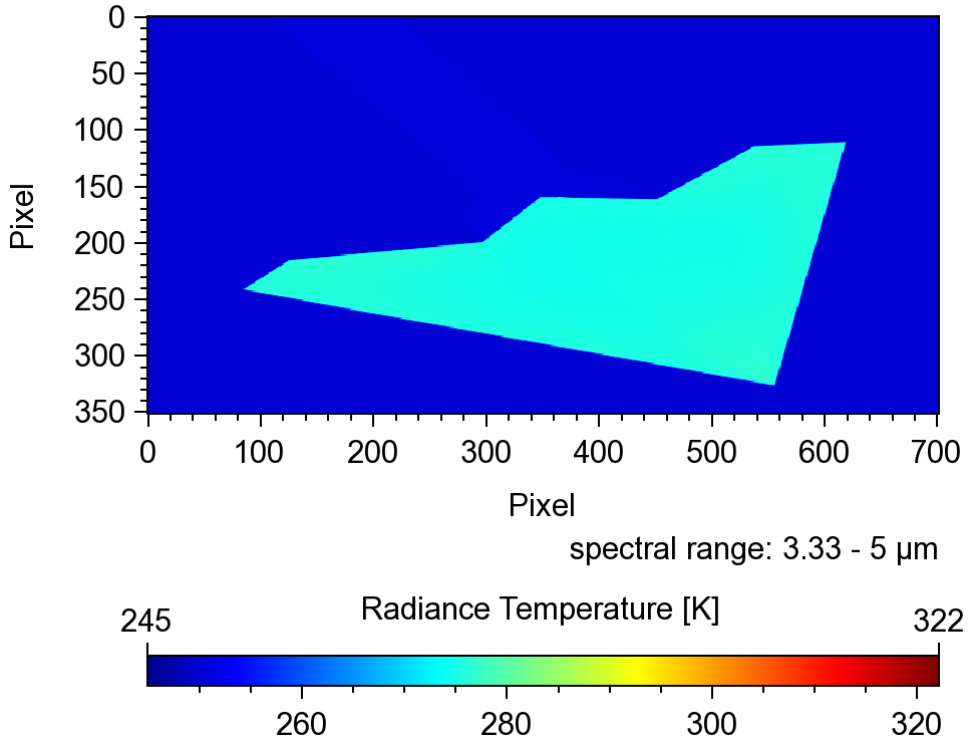
IR-Signature of MULDICON at altitude 5 km

Velocity Mach 0.8, distance 5 km, homogeneous background

Off-tail angle 165°, elevation 25°



Off-tail angle 30°, elevation –25°



MIRA´s Terrain Model

Purpose

Improve realism by a structured background

Current state

First Version: DEM + Classification

Scene:

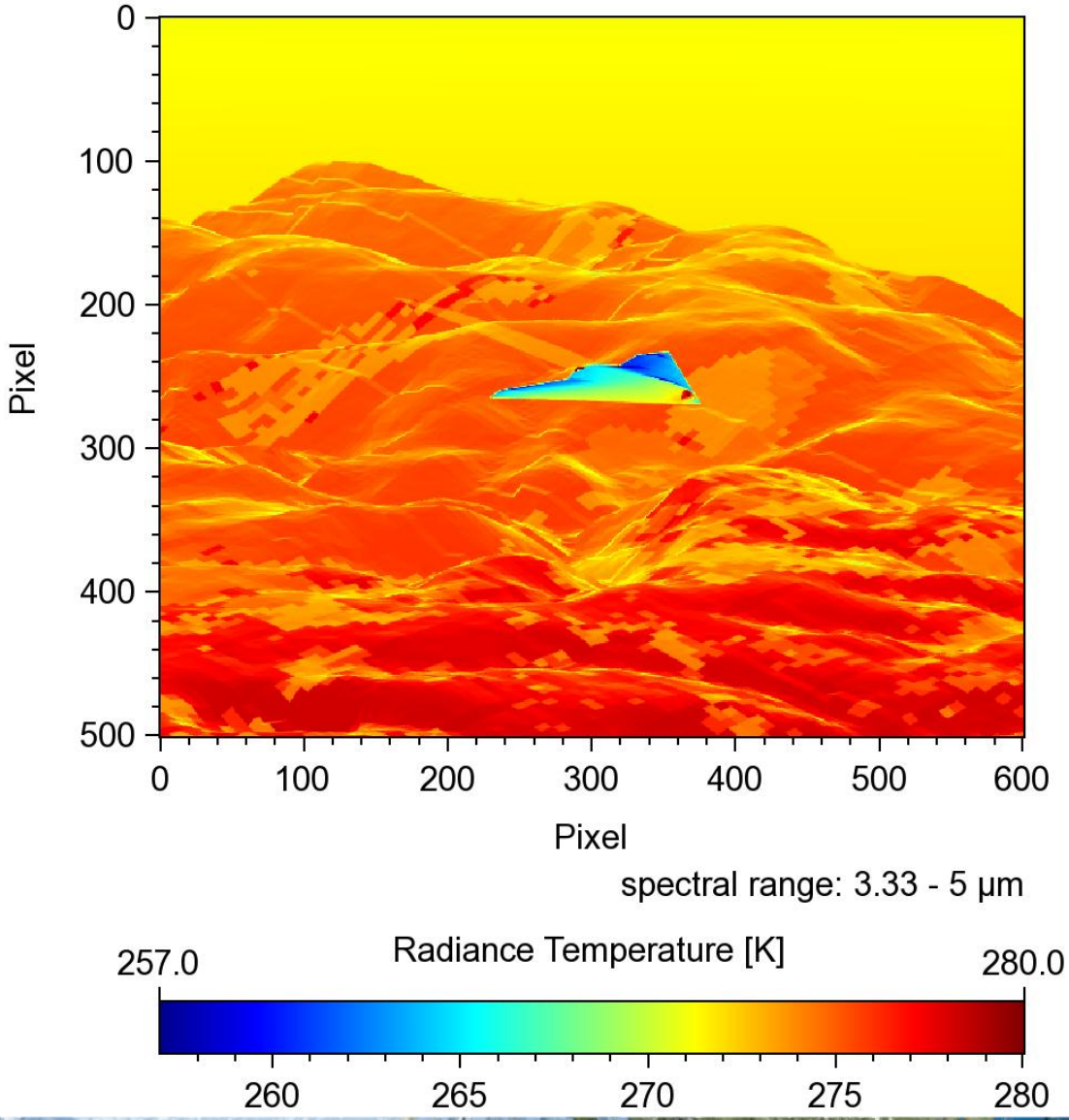
MULDICON in front of Mt. Brocken in the Harz area of Germany

Data:

DEM Area: 135 km x 110 km

Classification derived from satellite data

(Source: DLR´s German Remote Sensing Data Center)



Summary and Outlook

IR-Signature Model MIRA

- Introduction of the IR-Signature Model MIRA
- Requirements, treatment of multiple reflections, terrain model

MULDICON design

- Application of MIRA to aid the design (exhaust duct) by IR-signature predictions
- Result: Exhaust gas emissions minimized, but skin reflection/emission problematic

Next Steps

- MIRA: Improved terrain model + structured sky (clouds)
- Investigations to lower the IR emission of MULDICON´s airframe